AD-403740

JPRS: 18,206

OTS: 63-21354

19 March 1963

MAIN FILE

TRANSLATIONS ON APPLIED BIOLOGY

- USSR -

U. S. DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES
JOINT PUBLICATIONS RESEARCH SERVICE
Building T-30
Ohio Dr. and Independence Ave., S.W.
Washington 25, D. C.

Best Available Copy

FOREWORD

This publication was prepared under contract for the Joint Publications Research Service as a translation or foreign-language research service to the various federal government departments.

The contents of this material in no way represent the policies, views or attitudes of the U. S. Government or of the parties to any distribution arrangement.

PROCUREMENT OF JPRS REPORTS

All JPRS reports may be ordered from the Office of Technical Services. Reports published prior to 1 February 1963 can be provided, for the most part, only in photocopy (xerox). Those published after 1 February 1963 will be provided in printed form.

Details on special subscription arrangements for JPRS social science reports will be provided upon request.

No cumulative subject index or catalog of all JPRS reports has been compiled.

All JPRS reports are listed in the Monthly Catalog of U. S. Government Publications, available on subscription at $4.50 per year ($6.00 foreign), including an annual index, from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

All JPRS scientific and technical reports are cataloged and subject-indexed in Technical Translations, published semimonthly by the Office of Technical Services, and also available on subscription ($12.00 per year domestic, $16.00 foreign) from the Superintendent of Documents. Semiannual indexes to Technical Translations are available at additional cost.

JPRS: 18,206

TRANSLATIONS ON APPLIED BIOLOGY

-USSR-

[Following is the translation of two articles from the Russian-language publication Byulleten' Moskovskogo Obshchestva Ispytateley Prirody, otdel biologii (Bulletin of the Moscow Society of Naturalists, Biology Section), Vol LXVII (5), Moscow, 1962. Additional bibliographic data accompanies each article.]

TABLE OF CONTENTS

ON THE ADAPTATIONS OF CETACEANS TO RAPID SWIMMING AND THE POSSIBILITY OF USING THESE ADAPTATIONS IN SHIPBUILDING

/Following is the translation of an article by A. G. Tomilin in the Russian-language publication Byulleten' Moskovskogo Obshchestva Ispytateley Prirody, otdel biologii (Bulletin of the Moscow Society of Naturalists, biology section), Vol LXVII (5), Moscow, 1962, pages 10-18./

In the world of living nature there are about 1.5 million various species of animals. All these are remarkably well adapted to their environment. Such adaptiveness is the result of natural selection, that is, the survival of the most progressive and the perishing of the unprogressive forms. Selection in nature operates on the smallest details of any character of any species. The fineness and perfection of the adaptations is explained by the prolonged and unceasing action of selection, rounding off those characters which most of all correspond to the conditions of life in a given environment.

This general principle in the organic world is observed also in water animals, for which swiftness of movement represents an essential advantage in the struggle for existence. The "clever" achievements of the animate world, built up step by step over millions of years can be used in the interests of man, and in particular, those adaptations providing the water animal with its high rate of movement can be borrowed for practical purposes. The close investigation of such adaptations in fast-swimming water animals can prove to render valuable ideas in increasing the speed of ships without raising the engine capacity. Such an idea was first introduced by us at a scientific and technical conference of the Leningrad Higher Ship Engineering College imeni Admiral Makarov by Engineer Z. M. Afonin (1961) and the author of the present article, Tomilin (1961).

Most accessible for study from this point of view of the water animals are the cetaceans -- highly organized and specialized forms capable of attaining high speed in free movement both singly as well as in entire shoals. Many of these easily outswim the fishes which they consume. The main organ for the movement of cetaceans is the laterally compressed section, the tail stock, at the rear end of which are two broad lateral extensions, the

tail fins, ordinarily called the flukes. The tail stock itself executes up - down movements, and the flukes assume various angles of slope to the lengthwise axis of the tail stock. The frequency and scope of the tail stock blows and the angle of inclination of the flukes affects the speed of the animal's movement. Dolphins of 210 cm length, swimming at a speed of 33.3 km per hour, flap their tails at the rate of 3.4 times a second, and at a 2.5 times per second rate they swim up to 16.7 km per hour (Schevill, 1961).

Besides direct evidence of the swimming rate of the cetaceans we also find evidence of the high locomotive properties of these animals in the great leaps above the water's surface that they perform, their indefatigibility in migrations extending for thousands of kilometers, cases of long distances covered by whales with severed flukes, and the phenomenon of "wave riding" by dolphins.

Direct data on the swiftness of the movement of freely swimming cetaceans have been accumulated during the activities of the dolphin-hunting and whale-hunting industries -- in pursuit after prey, and also through observations of playing (gamboling) dolphins, and especially observations of cetaceans trailing after ships. The remarkable habit of trailing ships permits a precise determination of the speed of these animals. This habit, which is not yet fully understood, is characteristic of many species of the order (Tomilin, 1937, 1957) and generally is observed as short pursuits, lasting from several seconds to several dozens of minutes. In addition, the very rare instances of persistent following of ships for many days by the blue and the humpback whales are known. Iokhansen and Garden (Johannessen and Harder, 1960) have gathered special information on the speed of the toothed whales from the high-speed American ship "Monterey", amounting to 36-39 km/hr. From this ship it was observed that the Liocassis-odinochka [?] swam for 20 minutes at speeds varying from 38 to 55 km/hr, and large groups of grampus numbering 200-500 members maintained speeds of 26-33 km/hr for 8-25 minutes. A similar speed (36 km) for a shoal of grampus has been established by Shuleykin, Luk'yanova, Stas' (1937). But the grampus can, apparently, outswim the Liocassis, in whose stomach remains of grampus have not yet been found.

Of the Mystacoceti the rorquals are the fastest. Whale hunts have established that following the unsuccessful firing of a harpoon, lightly wounded sei whales (12-15 m in length) can dash for short distances at a speed of almost 55, and the finbacks (20 m in length) -- up to 50 km/hr.

Cetaceans maintain a considerable speed even for large artificial loads, for example, when harpooned whales drag behind them a whaleboat or a broken line, for the "hooked" dolphins can tow the boats.

In our whale-hunting practice of 1934, when the hunting techniques were not yet perfected, such cases were frequently noticed. On 23 November an adult female (19.5 m in length) broke

a line and with 50 m of extended line swam from the researchers at a speed of 26 km/hr for more than an hour (later it was caught by a second harpoon). On 3 December a wounded finback (19.7 m in length), drawing out the entire length of line (1125 m) still kept it extended even against the full force of the ship's forward movement, making 25 km/hr. More than once it turned out that when wounded finbacks towed the whale-hunting ships "Avanguard", "Enthusiast", and "Trudfront" (displacement of 260 tons) at a speed of 3-5 km/hr even with slow reverse engines, with an 890 hp capacity. In the old literature (Scammon, 1874) we find recorded the fact that one finback, running across an anchor, pulled a schooner from its roadstead and towed it at a speed of 22 km/hr.

Analogous facts are known also for the smaller cetaceans. The author was a witness to an adult grampus (170 cm in length) being "harnessed" in a felucca (about 2 tons in capacity) containing six fisherman and how the animal pulled this load from Novyy to Staryy Gagra at the rate of a man walking. A dappled dolphin in the Gulf of Mexico swam near the prow of a ship at a speed of 18.5 km/hr in spite of a remora fish 50 cm in length affixed to its spine (Mahnken and Gilmore, 1960).

Cetaceans are able to make high leaps, possible only at high speed. Aphalins [?] and grampus can spring up to heights of 4-5 m. Aphalins can leap completely free of the water even alongside the shore where the water is only 2-3 m deep, or in artificial basins having a diameter of not more than 20 m. The high leaps of the dolphins and their complete emergence from the water even in narrow spaces substantiates not only the high speed of these animals but also the efficiency of their movement, which seems to be disproportionate to their muscular strength.

The efficiency, facility, and swiftness of movement enables cetaceans annually to complete enormous seasonal migrations over distances of thousands of kilometers between cold (sometimes polar) and warm (sub-tropical) waters. Pointing to the high efficiency of movement is the case of a capture along the migration routes of a grey whale with both flukes severed some time in the past. This whale could move only by thrashing his tail stock, not in the usual up-and-down direction, but laterally, as a fish -- right-to-left; as it advanced the whale tipped to one side and thrashed with his tail stock right-to-left (that is, up-and-down) and before it emerged at the surface it rotated its body (blow-hole) upwards, in order to breathe. In spite of all this labor, the maimed whale covered a distance of more than 6,000 km in 70-79 days (Gilmore, 1960).

The perfection of the adaptations to movement in water that are found in dolphins is confirmed by the phenomenon of "wave riding". This is the name given to the cases of passive gliding of dolphins along the prow of a ship, when their flukes are kept still, but their bodies nonetheless glide (sometimes for hundreds of meters!) along the wave produced at the prow of a ship. The

wave, striking the immobile fluke, lightly thrusts against the dolphin's body with the ship's speed. Such gliding in the wake of a ship moving at 19 km/hr lasts for 5 minutes. Fedzher and Bakkus (Fejer and Backus, 1960) have established that even small wind-driven waves, with an angle of 10-18° and a speed of 5-6 m/sec can be ridden by dolphins. Shore-side waves (in shallows) are ridden by entire shoals of 12-15 aphalins [?], passively moving with the wave for distances up to 227 m (Caldwell and Fields, 1959).

The postures used by dolphins in riding waves evidences their use of the thrusting force of the wave by their entire body, not only by the ventral surface of the flukes (Yuen, 1961).

How can such adaptations be explained and what makes for the high speed of cetaceans?

In connection with this question, of special importance is the fact established through experiments that a form closely reproducing the weight and contour of a dolphin, to which its strength corresponds, moves much more slowly than a live dolphin. Kramer (1960 a, b) showed that the dolphin has a resistance in the water one-tenth that of the model with the usual sheathing of the same size and form. It is obvious that the rapidity of cetaceans rests not only on the form of the body and the strong musculature of the tail stock alone.

In reality the high speed of these animals is explained by the following: 1) the specific structure of the skin covering exhibiting hydrophobic, anti-turbulent, and damping properties; 2) a well-developed driving mechanism in the sheath, inducing a whirling stream about the fast-moving body; and 3) the highly streamlined form of the entire body and also of its parts.

The adaptations in the sheaths which decrease the resistance of friction arise from the following: 1) by way of the formation of a non-wettable (hydrophobic) skin, and 2) by way of the formation of elastic (flexible) and damping structure of the skin, which reduce the turbulence of the stream arising from the rapid movement of the body in water, and promotes the conversion of the turbulent conditions of the wake into laminar.

The non-wettability (hydrophobicity) in cetaceans is achieved by the very quality of the skin material; in the whale industry it can be seen how dolphins lifted from the water instantly become dry externally, and captured whales lying on board and swept by high waves do not show any drops or traces of moisture after the wave has passed, since the water instantly streams off the bodies of the animals.

As far as the interaction of the hydrophobic materials with water is concerned, Z. M. Afonin (1961) wrote: "Hydromechanics bases its theory of the resistance of friction on the hypothesis of the adherence of the nearest layer of liquid to the surface of the moving body. This is wholly valid for materials usually employed in practice. But what happens with this layer of liquid, if the material of the body surface is hydrophobic? According to

the idea of the physical chemists (Professor A. A. Glagoleva) the water molecules can aggregate into groups that are linear or bulky (including circular) in structure. The surface of the hydrophobic material has a property of so acting on the immediate layer of water that the molecules of this liquid join in circular structures. In such cases the surface of the hydrophobic body moving in the water spins, as it were, on ball bearings." If this is so, then the hydrophobicity of the skin must be recognized as a very important adaptation to fast swimming, reducing the tangential frictional forces.

Another most important character of the skin of cetaceans is its anti-turbulent property. Kramer (1960 a, b), using the principles of dolphin skin structure, made an artificial skin called "laminflo". A model of a torpedo clothed in this skin moved 50% more rapidly than an analogous model with the same propulsive force, but with the usual sheathing. In order to understand how successful this imitation of dolphin skin was, it is necessary to compare the structure of the covering of cetaceans with the structure of the "laminflo" covering.

The skin of most species of whales and dolphins from top to bottom is completely unkeratinized and is built on a single design principle, which has been described in detail by V. Ye. Sokolov (1955, 1960 a, b) (Figure 1). In the epidermis under the outer fine layer (stratum corneum) a growth layer is situated, in the ribbed cells of which from below flexible prickly papilla of the dermis emerge singly from below in a direction perpendicular to the skin surface (the "rods", in the terminology of Kramer, 1960). These skin papilla are very flexible, since along their axis lie fine collagenous and elastin fibers, and also blood capillaries. Under the skin papilla we find a very dense nest of bundles of collagenous fibers, lying at small and acute angles to the skin's surface. Going more deeply, the nest becomes looser, the fibers become blunter, and fat cells appear among them. Even further down the skin grades off inperceptibly into the subcutaneous cellular tissue or fatty layer, permeated sparsely with scattered collagenous funiculi, the space between being filled with fat. In the lower part of the layer, close to the subcutaneous musculature, the network of collagenous funiculi increases again in size, and the funiculi become even blunter. The elastin fibers usually pass alongside the collagenous funiculi. The epidermis and skin papilla are best developed where the skin experiences the greatest water pressure during forward movement (frontal part of the head, the anterior edges of the flukes, etc.). This points to the role of the skin as a damper of the frictional forces during movement in a fluid environment.

What then of the sheath structure described did Kramer borrow to produce his artificial skin -- the "laminflo" sheathing? The latter was made of flexible rubber and consisted of three layers: the upper being a smooth seamless covering (0.5 mm in thickness), having an elastic diaphragm with small flexible

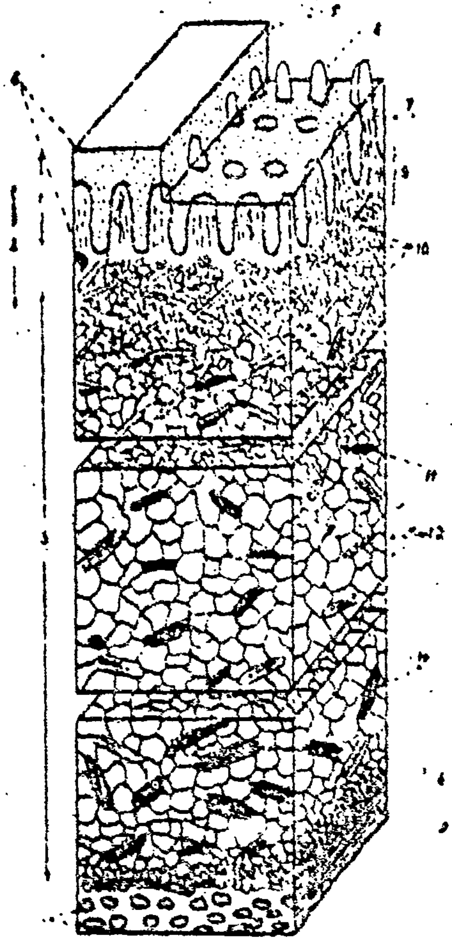


Fig. 1. Schematic section through the skin of a whale (after V. A. Sokolov, 1960): 1 - epidermis; 2 - dermis; 3 - fat layer; 4 - subcutaneous musculature; 5 - upper layer of the epidermis stratum corneum; 6 - growth layer of the epidermis; 7 - pits of the growth layer; 8 - prickle papilla of the dermis; 9 - subpapillar layer of the dermis; 10 - funiculi of collagenous fibers; 11 - funiculi of elastin fibers; 12 - fat cells.

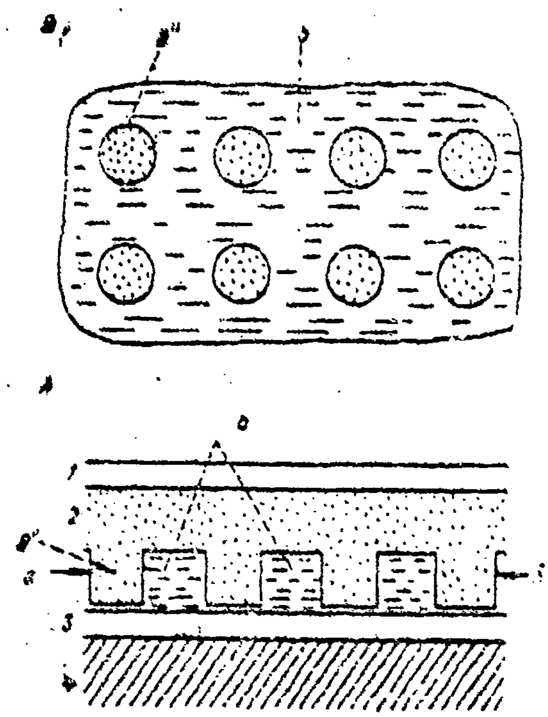


Fig. 2. Scheme of artificial skin-sheathing "laminflo" (after M. O. Kramer, 1960 b): A - lateral section; B - tangential section through the layer of shaftlets along the line ab; 1 - upper smooth seamless envelope; 2 - elastic diaphragm containing flexible shaftlets; 3 - lower seamless envelope; 4 - body of the model; 5 - space filled with damping fluid; 6 - flexible shaftlets.

apertures (total thickness 1.5 mm) and a lower seamless covering (0.5 mm), adjoining the body of the torpedo model (Figure 2, A. B). The intervals between the apertures bounded from below by a supporting covering, and from above by the lower side of the diaphragm, were filled with a damping fluid. The upper seamless covering imitated the fine horny smooth layer of the dolphin's skin, and the diaphragm with the finger-shaped apertures reproduced, as it were, the skin with its collagenous tissue; the damping liquid in the "laminflo" skin was an analogue to the liquid fat in the fatty layer of the dolphin's skin; the lower seamless covering served as the support sheath. The damping liquid in the "laminflo" skin upon experiencing pressure from above on the elastic diaphragm could be sent through the capillary spaces among the small apertures, overcoming the force of resistance and in this way acting as a damper of the oscillations and whirl induced in the adjoining layer of water.

Damping in the skin coverings of fast swimming dolphins is achieved through the smooth epidermis and the upper part of the flexible dermis at the sites of highest water resistance pressing in on the fluid fat, which as a result is circulated to the very narrow passages between the highly flexible collagenous fibers. The damping process in dolphin skins is accomplished much more effectively than in the "laminflo" sheathing, since in the dolphin the damping layer (dermis with papilla and fatty layer with collagenous tissue) is much thicker (several centimeters!), the capillarity is substantially finer, and the elasticity of the capillary passages is higher. In addition, the fat of cetaceans in the damping process exhibits two most valuable properties -- liquid consistency and high degree of wetting of the collagenous fibers. Therefore, it must be recognized that the "laminflo" sheathing is far from perfect, since in it Kramer did not take into account many details of the structure of the natural dolphin's skin, which can still further reduce the friction in the adjoining layer of the fluid environment.

For the fastest species of cetaceans (Liocassis, grampus, the bottle-nosed dolphin, and of the rorquals -- the finbacks) the network of elastic fibers in the skin is much more intensely developed in the slower species (Sokolov, 1960). This fact substantiates the importance of the elasticity and flexibility of the skin, assisting the damping of the water turbulence in the rapid passage of cetaceans. Due to the extreme elasticity of the integument the skin of cetaceans usually does not preserve any marks after vigorous collisions and traumas, and ncse wounds as a rule are spasmodically constricted, through which the wound opening is closed (it is probable that his is how wounded whales survive). In recent years in the whale-hunting industry the flexible carcases of whales have begun to be used as the best fenders /krantsy/.

Thus, cetaceans have at the same time both methods of reducing friction: the anti-turbulent properties of the skin and improved damping reduced friction so that the turbulent condition is converted

into a laminar, and the laminar friction in its turn is decreased by the hydrophobicity.

However, there is still another most important adaptation for friction reduction. The eddy streams arising around the fast-swimming body are produced by a motor mechanism of the skin itself. In the Florida Aquarium, transverse wavy ripples of the skin were noted for swimming aphalins at the moment of maximum speed (before a jump, or after), photographed by Essap'yan (Essapian, 1956). The importance of these ripples has thus far remained unclear. It is obvious that the movement of the skin and the very elastic subcutaneous musculature /See Note/ in the form of transverse ripples around the body begins when the speed of the dolphins reaches the critical value and when the water eddies cannot not be eliminated either by the hydrophobic or by the damping properties of the skin. The high mobility of the skin is characteristic also of large whales, which has been corroborated by instances of the repeated fracturing of the sword of swordfish imbedded in the body of blue whales upon collision with swordfish (Jonsgard, 1959). On this same principle markers placed in the bodies of whales almost always proved to be deformed, if they are fastened by one end into the blubber and by the other into the muscle (Clark and Ruud, 1954).

(/NOTE/ The high elasticity of the subcutaneous musculature results from the elastic fibers surrounding the muscle fibers (Sokolov, 1960 a, b).)

The transverse skin-muscular bands running along the body of cetaceans dampen the eddies induced through rapid movement and make high speeds possible. Precisely this serves to explain the rapid movement of large (sometimes in the thousands) shoals of dolphins, when it would appear that the eddy currents due to the close proximity of swimming specimens would reach very high rates of speed and make the rapid movement of the shoal impossible.

The high hydrodynamic properties of the contour of the body and flukes of whales are widely known. But besides the general form of the body streamlining is probably promoted in the rorquals of the order Balaenoptera by the very mobile and flexible longitudinal bands along the abdomen, and for almost all species of dolphins -- by the fat cushion on the head. Study of these adaptations, and their evaluation from the hydromechanics point of view can prove to be useful for practical purposes.

The size and number of bands (40-120) for various species of rorquals differ, but their arrangement for all species is the same -- on the abdominal side from the chin to the region of the navel. Would not the abdominal fold (in addition to their other functional values) serve as improved eddy current dampers, necessary for the movement in water of so long a body as we find for these whales (10-30 m)?

It is possible that the fat cushion on the head (in the frontal part) of dolphins is also an important adaptation for rapid movement in water. The value of this organ (undoubtedly

multi-functional) has not yet been discovered, but it can be assumed that the elastic fat cushion situated below the skin serves as a superlative damper, which does not permit any turbulence from the very front to the rearmost part of the moving body. The laws of hydrodynamics state that such turbulence would be especially disadvantageous, since it would sharply reduce the speed of the animal. It is not by chance that all small and large dolphins have a fat cushion streamlining the water flow about the body (especially during leaps). Let us recall in this connection that during times of wave production and swells ships are greatly impeded in progress. Could not damping structures analogous to the fat cushions help to eliminate this defect, if they were situated at the very prow of the ship, which is most vigorously thrust upon by the oncoming wave?

Conclusions

1. The principles of the adaptation of water animals to rapid movement -- their anti-turbulent and hydrophobic properties of the skin coverings -- can be used as techniques for increasing ship's speed (Afonin, 1961; Tomilin, 1961).

2. Cetaceans are the most valuable objects for study of these adaptations, which reduce frictional resistance and result in the high rates of movement of these animals. The following features assure the high speed of cetaceans: a) the specific structure of the skin cover exhibiting hydrophobic and anti-turbulent properties; b) the development of a motor mechanism in the integument, producing eddies around the moving body; c) the development of highly streamlined body forms and a strong musculature.

3. The study of these adaptations must be carried out on the fastest moving species of cetaceans (Liocassis, grampus, and actual rorquals) both experimentally under laboratory conditions, and also through observations and experiments in the natural habitat -- in the sea and in aquaria. In the first place it is necessary to carefully study the phenomenon of damping in the dolphin integument in order to more precisely duplicate the skin of cetaceans when preparing the artificial anti-turbulent and hydrophobic sheathing.

4. In evaluating the quality of the imitation it is advisable to conduct towing experiments at identical speeds of a freshly killed dolphin, a dolphin dressed in the artificial sheathing-skin, and a controlled model with the usual sheathing.

5. Speed tests should be conducted for grooved models -- analogous to the abdominal bands of rorquals and analogous to the fat cushions of dolphins.

LITERATURE

Afonin, Z. M., 1961. Tezy k nauch.-tekhn. konf. prof.-prepod. sostava Leningradskogo vysshogo inzhenerskogo morskogo uchilishcha imeni admiraly Makarova /Abstracts from the Scientific and Technical Conference of the Vocational Teaching Staff at the Leningrad Higher Ship Engineering College imeni Admiral Makarov/, pages 18-19.

Sokolov, V. Ye., 1955. Byull. MOIP, otd. biol. /Bulletin of the Moscow Society of Naturalists, Biology Section/, Vol 60, No 6.

Sokolov, V. Ye., 1960 a. Zoologicheskiy Zhurnal, Vol 39, No 2.

Sokolov, V. Ye., 1960 b. Nature, Vol 185, No 4715.

Tomilin, A. G., 1937. Priroda /Nature/, No 1.

Tomilin, A. G., 1957. "Kitoobraznyye," /Cetaceans/, Zveri SSSR i Prelezhashchikh Stran /Animals of the USSR and Adjoining Countries/, Vol IX, Moscow-Leningrad.

Tomilin, A. G., 1961. Tezy k nauch.-tekhn. konf. prof.-prepod. sostava Leningradskogo vyssh. inzh. morsk. uch. im. adm. Makarova, pages 26-28.

Shuleykin, V., Luk'yanov, V. and Stas', I., 1937. Izvestiya AN SSSR, ser. geografii i geofiziki /News of the Academy of Sciences, Geography and Geophysics Series/, No 4.

Clarke, R. and Ruud, J. T., 1954. Norsk hvalfangst-tidende, Vol 43, No 3.

Caldwell, D. K. and Fields, H. M., 1959. J. Mammal., Vol 40, No 3.

Eassapian, F. S., 1955. Breviora Museum of Comparative Zool., Cambridge, Mass., No 43.

Fejer, A. A. and Backus, 1960. Nature, Vol 188, No 4752.

Gilmore, R. M., 1959. Pacific Naturalist, Vol I, No 9.

Gordon, M. S., 1961. Science, Vol 133, No 3447.

Johannessen, C. L., and Harder, J. A., 1960. Science, Vol 132, No 3439.

Jonsgard, A., 1959. Norsk hvalfangst-tidende, Vol 48, No 7.

Kramer, M. O., 1960 a. New Scientist, Vol 7, No 181.

Kramer, M. O., 1960 b. J. Amer. Soc. Naval Engrs, Vol 72, No 1.

Mahnken, T. and Gilmore R. M., 1960. J. Mammal., Vol 41, No 1.

Scammon, C M., 1874. The Marine Mammals of Northwestern North America, San Francisco.

Schevill, W. E., 1961. "Cetacea," Encyclopedia of the Biological Sciences, New York.

Yuen, H. S., 1961. Science, Vol 134, No 3484.

10,123
CSO: 2512-S

THE EFFECT OF VARIOUS BIOMASSES OF WATER PLANTS ON TRACE CONCENTRATIONS OF CESIUM AND STRONTIUM IN TANKS WITH A LOW FLOW RATE

/Following is the translation of an article by A. L. Agre, A. P. Raiko, and N. V. Timofeyev-Resovskiy, in the Russian-language publication Byulleten' Moskovskogo Obshchestva Ispytateley Prirody, otdel biologii (Bulletin of the Moscow Society of Naturalists, biology section), Vol LXVII (5), Moscow, 1962, pages 120-127./

The ability of slow-flowing reservoirs to purify the water passing through them from trace concentrations of radioactive isotopes has been established by several experimental investigations (Timofeyev-Resovskaya, 1957; Agafonov, 1958; Agre, 1962; and others).

However, still remaining unsolved is the question as to the quantitative effect of the biomass of the water flora and fauna, including water plants, in the process of purifying the water from the trace quantities of radioactive isotopes present therein. Such data are necessary to predict the fate of trace amounts of radioisotopes placed in the reservoir and to forecast their migration into the components of the reservoir. This is of interest both from the point of view of studying the migration path taken by diffused elements and trace elements in various parts of the biosphere, as well as from the practical point of view -- for purposes of deactivating water and evaluating the sanitary and hygenic hazard of reservoirs contaminated by radioactivity.

The task of the present study includes the discovery of what effect the quantity of water plants present in slow-flowing reservoirs has on how much the water passing through is deactivated from the strontium and cesium present, and also what effect the water plant quantity has on the value of the secondary contamination of the water.

Methods of investigation. Experiments were conducted in low flow rate tanks arranged in a cascade fashion, imitating slow-flowing reservoirs /See Note/. Six series of tanks were used for the experiment. The series consisted of four tanks of 30 l capacity each. Three series of tanks were designated to be used in conducting experiments with water contaminated by cesium-137, and three -- for experiments with strontium-90. The first series of tanks were loaded with an equal amount of earth (sand plus stratified garden

the sorption and following the desorption period. The cesium content in the water plants and the coefficients of cesium accumulation by the plants are given as totals for all species of plants. Table 3 presents data indicating the change in the amount of cesium-137 in the water, earth, and water plants following the desorption period.

Upon passing water containing trace amounts of strontium-90 through the system of tanks, deactivation of the water was also realized, but to a lesser extent for cesium-137. In experiments with strontium and water passing through all the tanks of the various series, we also noted a differing amount of cesium both in the sorption period and in the desorption period. Data on the amount of strontium passing through all the tanks and remaining in the outflowing water are presented in Table 4.

Table 5 shows the content and distribution of cesium in the water, earth, and water plants (as totals) following the periods of sorption and desorption, and also lists the coefficients of strontium accumulations by the water plants.

Table 6 shows the change in the amount of strontium in the water, earth, and water plants following the desorption period in percentages of the amount of strontium contained in the water, earth, and water plants during the sorption period.

Discussion of the Results Obtained

The data obtained in these experiments on the effect of various biomasses of water plants on the extent of the deactivation of water containing the isotopes strontium and cesium although preliminary nonetheless have afforded a completely clear and definite positive answer. It is enough to compare the results of the determination of residual cesium and strontium content in water passing through the tank system as presented in Tables 1 and 4 in order to see that during the sorption period water containing cesium-137 is purified twice as much, and water containing strontium-90 -- almost six times as much in the tanks of the first series containing a large amount of water plants than the tanks in the third series, where no water plants were placed. Upon passing through contaminated tanks pure lake water (period of desorption) the latter was contaminated also considerably less if the tanks contained a large amount of water plants. In this case the water passing through the first series tanks was contaminated by cesium one-sixth as much and by strontium one-fourth as much as in the third series tanks (Tables 1 and 4).

Comparing the efficiency in deactivating water from cesium-137 and strontium-90 in low flow rate tanks, we must emphasize the better sorbibility of cesium by water plants and the greater migrational capacity of strontium.

It can be noted that according to the classification of N. V. Timofeyev-Resovskaya strontium is among those elements

in the earth of the first and second series tanks (Tables 3 and 6.)

In our experiments very high accumulation coefficients of the trace amounts of radioisotopes by the water plants were obtained. On an average, the coefficients of cesium accumulation by water plants equalled two orders of magnitude, and for strontium -- two to three orders. It must be noted that the accumulation coefficients both for cesium and for strontium show a tendency to increase with decrease in element concentration in the water (Table 2 and 5).

The total content of cesium and strontium in the water plants following the desorption period changed, but not substantially (50%) and the rate of strontium and cesium loss by the water plants lagged considerably behind the rate of decrease in the cesium and strontium concentrations in the water (Tables 3 and 6).

Upon our request, V. Bukhovtsev (for the work done, we take this opportunity to express our deep thanks) calculated the process of the ideal dil tion of solution of matter fed into a system consisting of four tanks of 30 l capacity and with a daily solution feedrate of 1/30th of the total volume of the entire system. The figure shows the curves of change in the solution concentration for each of four tanks from the moment of the onset of feed supply up through the thirtieth day. If we compare the data of the actual experiment describ d in this report with that of the ideal conditions of dilution, then we sketch out the following situation. Theoretically, by the thirtieth day 17.5% of the matter must have exited from the four-tank system, and 82.5% must remain behind in the system, in which the first tank will hold 100%, that is the concentration in the water will equal the concentration of the solutions supplied, in the second tank --91.5%, in the third tank -- 78.5%, and in the fourth -- 60% of the original solution concentration. Under actual conditions we have the following: in the experiment with cesium 0.8% in the first series and 1.7% in the third series, and in the experiment with strontium, 1.2% in the first series, and 6.4% in the third series, left the tanks relative to the total amount of isotopes supplied It turns out that the amount of cesium exiting from the first series tanks is one over 21.6, and from the third series one-tenth that of the theoretically calculated amount. The amount of strontium in the first series is one over 14.5 and in the third series one over 2.7 that of the theoretical figure.

Thus, as could be anticipated, only strontium, as a very mobile and difficultly sorbed element, approximates in its behavior under the given experimental conditions to values close to the ideal.

A detailed analysis of data on the quantitative ratio in the cesium and strontium distribution by components (water, earth, and biomass), and by tanks, and also a comparison of the experimental

soil) and were planted with equal amounts of seven species of water plants (Elodea, Ceratophyllum [hornwort], Hydrocharis [frogbit], Myriophyllum [foxtail], Stratiotes [water soldier], Ranunculus [water buttercup], and Lemna [duckweed]). The second series was filled with the same amount of earth, but the quantity of water plants in the tanks was 15th of that in the first series. The plants in the second series were of four species -- foxtail, duckweed, water buttercup, and hornwort. The third series contained no earth or water plants, only the bottoms of the tanks were lightly sifted over with sand. All the tanks were filled with pure lake water.

The experiment on deactivating water from cesium-137 and strontium-90 lasted for 50 days and consisted of two periods. During the first period, called the sorption period, lake water containing a solution of cesium or strontium with a concentration equal to 10^{-6} curies/liters in radioactivity, with a water flow of 4 l per day was passed through the tanks. The first period lasted for 30 days. During the second period, called the desorption period, pure lake water without cesium or strontium passed through the tanks. The second experimental period lasted for 20 days. During the course of the entire experiment samples of water which had passed through the entire system of the tanks were taken. Samples of water, earth, and water plants from all the tanks of all the series of the experiments were taken after 30 days (the sorption period) and after 50 days (the desorption period). The arrangement and treatment of the water, earth, and plant samples, and the measurements of their radioactivity were carried out according to the generally accepted methods.

<u>Results of the investigations</u>. In passing through cesium-137-contaminated water, an almost complete purification of the water was realized. But in various series the amounts of cesium passing through all the tanks differed both in the sorption period and in the desorption period. The average data on the amount of cesium passing through all tanks and remaining in the outflowing water are presented in Table 1.

Table 1

Amount of Cesium-137 Exiting From the Tanks in Percentages of the Original Value

(a) Период опыта	(b) Серия баков		
	(c) первая	(d) вторая	(e) третья
Сорбция (f)	0,8	1,7	1,7
Десорбция (g)	1,1	3,3	0,6

LEGEND: a) Experimental period; b) Series of tanks; c) first; d) second; e) third; f) Sorption; g) Desorption.

Table 2 presents the results of measurements of the radioactivity of the samples of water, earth, and water plants following

Table 2

Amount of Cesium-137 in Water, Earth, and Water Plants in Various Tanks Following the Periods of Sorption and Desorption (In Counts/min/g)

(a) Компоненты	(b) Серия и № бачков											
	(c) первая				(d) вторая				(e) третья			
	1	2	3	4	1	2	3	4	1	2	3	4
(f) Вода												
Исходная (g)	820	—	—	—	650	—	—	—	570	—	—	—
Сорбция (h)	454	132	40	11	335	128	64	31	350	159	68	23
В % от исходной (i)	55	16	5	1	48	19	9	4	61	23	13	3
Десорбция (j)	8	16	14	9	8	14	12	12	16	146	16	11
(k) Грунт												
Сорбция (l)	100	100	200	10	800	266	600	100	4200	2200	500	100
Десорбция (m)	1900	600	300	100	300	300	760	200	5000	2500	2100	300
(n) Водные растения												
Сорбция × 10³ (o)	100	47	15	5	105	45	17	8,5	—	—	—	—
Десорбция × 10³ (p)	34	31	21	11	90	40	27	15	—	—	—	—
(q) Коэффициенты накопления водных растений												
Сорбция (r)	342	371	371	44[illegible]	325	350	275	300	—	—	—	—
Десорбция (s)	5100	2000	1500	1200	1200	3000	2000	1100	—	—	—	—

LEGEND: a) Components; b) Series and No of Tanks; c) first; d) second; e) third; f) water; g) Original; h) Sorption; i) In % of original; j) Desorption; k) Earth; l) Sorption; m) Desorption; n) Water plants; o) Sorption x 10^3; p) Desorption x 10^3; q) Coefficients of water plant accumulation; r) Sorption; s) Desorption.

Table 3

Amount of Cesium-137 in Water, Earth, and Water Plants in Desorption Period (In Percentages of the Sorption Period)

(a) Компоненты	(b) Серия и № бачков											
	(c) первая				(d) вторая				(e) третья			
	1	2	3	4	1	2	3	4	1	2	3	4
Вода (f)	1,8	12,1	35,2	81,3	2,3	10,8	18,7	38,1	5,0	98,3	23,5	50,0
Грунт (g)	1900,0	800,0	150,0	1000,0	110,0	150,0	110,0	200,0	60,0	110,0	120,0	300,0
Водные растения (h)	34,0	65,0	140,0	220,0	80,0	89,0	160,0	170,0	—	—	—	—

LEGEND: a) Components; b) Series and No of Tanks; c) first; d) second; e) third; f) water; g) earth; h) Water plants.

Table 4

Amount of Strontium-90 Exiting from the Tanks in Percentages of the Original Value

(a) Период опыта	(b) Серия бачков		
	(c) первая	(d) вторая	(e) третья
Сорбция (f)	1.2	3.2	6.4
Десорбция (g)	8.1	17.7	34.4

LEGEND: a) Experimental period; b) Series of tanks; c) first; d) second; e) third; f) Sorption; g) Desorption.

Table 5

Amount of Strontium-90 in Water, Earth, Water Plants, and in Various Tanks Following the Periods of Sorption and Desorption (In Counts/min/g)

(a) Компоненты	(b) Серия и № бачков											
	(c) первая				(d) вторая				(e) третья			
	1	2	3	4	1	2	3	4	1	2	3	1
Вода (f)												
Исходная (g)	660	—	—	—	630	—	—	—	770	—	—	—
Сорбция (h)	457	184	71	11	504	313	166	74	647	463	306	156
В % от исходного (i)	70	28	11	2	80	50	26	12	84	60	31	26
Десорбция (j)	77	94	34	46	45	71	82	92	65	130	211	221
Грунт (k)												
Сорбция (l)	600	100	170	28	830	800	305	100	1600	1300	100	450
Десорбция (m)	2200	100	400	700	4400	3500	2300	700	2800	1600	1600	250
Водные растения (n)												
Сорбция × 10² (o)	320	177	60	23	400	350	175	95	—	—	—	—
Десорбция × 10² (p)	125	137	104	68	95	140	140	150	—	—	—	—
Коэффициент накопления водных растений (q)												
Сорбция (r)	750	950	850	2000	750	1100	1100	1300	—	—	—	—
Десорбция (s)	1650	1340	1200	1500	2200	2000	1700	1700	—	—	—	—

LEGEND: a) Components; b) Series and No of Tanks; c) first; d) second; e) third; f) water; g) Original; h) Sorption; i) In % of original; j) Desorption; k) Earth; l) Sorption; m) Desorption; n) Water plants; o) Sorption x 10²; p) Desorption x 10²; q) Coefficient of water plant accumulation; r) Sorption; s) Desorption.

Table 6

Amount of Strontium-90 in Water, Earth, and Water Plants During the Desorption Period (In Percentages of the Sorption Period)

Components	b) Серия и № бачков											
	c) первая				d) вторая				e) третья			
	1	2	3	4	1	2	3	4	1	2	3	4
Вода . . . . f)	16,7	51,0	118	418	8,9	23,0	49,1	124	10,0	28,0	68,9	141
Грунт . . . . g)	360,0	100,0	255	250	550,0	430,0	760,0	700	160,0	120,0	400,0	220
Водные растения h)	40,0	78,5	173	300	23,7	40,0	80,0	157	—	—	—	—

LEGEND: b) Series and No of tanks; c) first; d) second; e) third; f) Water; g) Earth; h) Water plants.

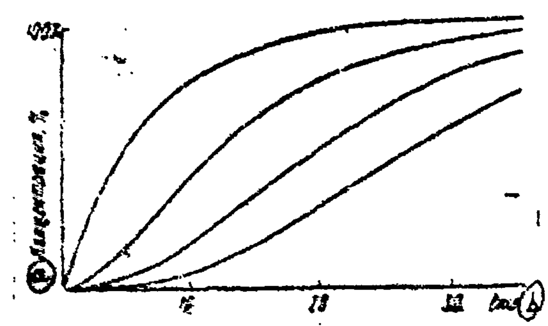
which are equally distributable between water, earth, and the biomass, and cesium -- is in that category of elements which are accumulated mainly in the biomass and in the earth. Therefore, also in our experiments on the biological deactivation of water, the role of water plants in removing precisely strontium from the water is more graphically seen.

Analysis of the data on the distribution of the cesium and strontium remaining in the tanks also shows the role of water plants in the process of isotope distribution by tank. If in the water of the first tanks of all three series an approximately equal amount of cesium was contained, then the water of the last tank of the first series contained 1% of the original cesium content, and

the third series -- 2.8%. Thus, the coefficient of water deactivation in the first series is almost three times better. Approximately the same ratio between the first and third series also holds for the desorption period; the amount of cesium in the water of the first tank of the first series was 1.8%, and in the third series -- 5% (Tables 2 and 3).

An even more graphic picture can be seen in experiments with strontium (Table 5). The coefficient of deactivation of water for the first series is 12.5 times better than for the third series. All data for the second series, as can be expected, lies in an intermediate position. Data on the cesium and strontium content in the earth of the tanks of various series also supports the role of biomasses in the process of isotope distribution (Table 2).

The figures presented in Table 2 show that the concentration of cesium in the earth drops down to one-tenth in the first series, and in the third series down to one-eighth, from the first tank to the last. In the experiment with strontium analogous ratios were obtained. The strontium concentration in the earth of the first series from the first tank to the last drops down to one-twentieth, and in the third series down to one-fourth. These data evidence the considerably slower migration of cesium and strontium in the earth of the tanks where the amount of water plants is greater.



Change in concentration in the tanks having a total volume of 120 l, the volume of tank No 1 being 30 l, and the daily flow = 4 l. LEGEND: a) Concentration, %; b) Days.

For the second period of the experiment, namely desorption it is interesting to note that not in a single tank was a decrease of the amount of cesium or strontium in the earth observed; on the contrary, a sizable increase took place, in spite of the large volume of pure lake water passed through (Tables 2, 3, 5 and 6). It seems to us that this fact can to a certain extent be explained by the fact that during the course of the experiment the earth was enriched by remains of perished earth plants, which not only carried with them accumulated strontium or cesium but also increased the stability of the bond of the sorbed isotopes with the earth. Also pointing to this is the increase in the cesium and strontium contents

data with the theoretically calculated data will be given in a subsequent article.

Conclusions

1. The presence of water plants in low flow rate tanks considerably affect the magnitude of the deactivation of water from cesium-137 and strontium-90. Under the given experimental conditions, water was purified from trace amounts of cesium twice as well, and from strontium -- five times as well in the presence of a large mass of water plants, and was secondarily contaminated by cesium one-sixth, and by strontium one-fourth less /in the presence of water plants compared to their absence/.

2. The deactivation coefficient, that is the ratio of the isotope concentration in the water in the first tank to the water in the last, is three times as high for cesium and for strontium twelve times as high for water plant-containing tanks as for tanks without plants.

3. The presence of water plants in the reservoirs and the variation in their amount sharply affects the nature and value of the trace element distribution among the reservoir components (water, earth, and biomass).

4. Experiments were conducted dealing with a forced regime of water flow, therefore, it can be expected that with a lesser flow the regularities shown will be manifest to a greater extent.

LITERATURE

Agafonov, B. M., 1958. "Laboratornyye opyty po biologicheskoy desaktivatsii vody v seriyakh vodoyemov-bachkov,"/Laboratory Experiments on the Biological Deactivation of Water in Series of Water-Reservoir Tanks/, Byulleten' Ural'skogo Otdela Mosk. Ob-va Ispyt. /Bulletin of the Urals Section of the Moscow Society of Naturalists/, No 1.

Agre, A. L., 1962. "Nekotoryye dannyye po migratsii radiostrontsiya i radiotseziya iz slaboprotochnykh vodoyemov," /Some Data on the Migration of Radiostrontium and Radiocesium from Low Flow-Rate Water Tanks/, Byull. Mosk. Ob-va Ispyt. otd. Biol., Vol 67, No 3.

Timofeyev-Resovskiy, N. V., 1957. "Primeneniye izlucheniy i izluchateley v eksperimental'noy biogeotsenologii," /Application of Radiation and Radiation Sources in Experimental Biogeocenology/, Botanicheskiy Zhurnal /Botanical Journal/, Vol 42, No 2.

Timofeyev-Resovskiy, N. V., Poryadkova, N. A., Sokurova, Ye. N., and Timofeyeva-Resovskaya, Ye. A., 1957. "Rabota po eksperimental'noy biogeotsenologii. I. Vliyaniye izluchateley na biomassu i strukturu nazemnykh, pochvennykh i presnovodnykh biotsenozov," /Work on Experimental Biogeocenology. I. Effect of Radiation Sources on the Biomass and Structure of Surface,

Soil, and Fresh-water Biocenoses/, Sbornik Rabot Laboratornay Biofiziki /Compilation of Laboratory Biophysics Studies/, Urals Affiliate of the Academy of Sciences USSR, No 1.

Timofeyeva-Resovskaya, Ye. A., 1957. "Pochvenno-biologicheskaya dezaktivatsiya vody v prudakh-otstoynikakh,"/Soil-Biological Deactivation of Water in Settlement Ponds/, Byull. Mosk. Ob-va Ispyt. otd. biol., Vol 62, No 1.

Timofeyeva-Resovskaya, Ye. A., Agafonov, B. M., Timofeyev-Resovskiy, N. V., 1957. "O pochvenno-biologicheskoy dezaktivatsii vody," /On the Soil-Biological Deactivation of Water/, Yubileynyy Sbornik UFAN /Jubilee Compilation of the Urals Affiliate of the Academy of Sciences USSR/, Sverdlovsk.

Timofeyeva-Resovskaya, Ye. A., Agafonov, B. M., and Timofeyev-Resovskiy, N. V., 1960. Sbornik Rabot Laboratornoy Biofiziki, Urals Affiliate of the Academy of Sciences USSR, No 3, Sverdlovsk.

10,123
CSO: 2512-S

-END-